STATE OF ILLINOIS

DWIGHT H. GREEN, Governor

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EDITED BY GRACE NEEDHAM OLIVER

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DWIGHT H. GREEN, *Governor*

DEPARTMENT OF REGISTRATION AND EDUCATION

FRANK G. THOMPSON, *Director*

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ANNOUNCEMENTS

Attention is directed to the fact that the Committee on Research Grants of the Illinois State Academy of Science has at its disposal a small sum of money to be disbursed in support of worthy research projects. Applications for grants will be accepted up to and including March 31, 1943. It is customary to give preference to scientists connected with the smaller institutions of the state.

Requests for grants should be accompanied by a brief statement of the training and experience of the applicant, the purpose of the investigation, and the estimated cost. Previous publications should be listed. At least two letters of recommendation should be transmitted directly by their authors. Correspondence may be addressed to L. H. Tiffany, Northwestern University, Evanston, Illinois.

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1943 MEETING: JACKSONVILLE, MAY 7-8

THE CONSERVATION RESEARCH PROGRAM OF THE ILLINOIS NATURAL HISTORY SURVEY

T. H. Frison*

APPLIED programs in the field of biological science are seldom, if ever, developed without the aid of years of patient, so-called unapplied, researches. If we assume that the present applied renewable natural resources program of the Illinois Natural History Survey is a feature of its work during the past decade, then we must acknowledge as the foundation of this newer program a previous half-century of basic, varied and monumental biological research by S. A. Forbes, former Chief of the Survey and past president of this Academy of Science, and his associates.

The early program of the Natural History Survey and its predecessors tends to separate into two phases of activity. One of these may best be characterized as a faunistic and floristic survey of Illinois, and resulted in such comprehensive reports as *The Ornithology of Illinois* by Robert Ridgway, and *The Fishes of Illinois* by S. A. Forbes and R. E. Richardson. The less inclusive reports are too numerous to mention specifically. They are varied in content, ranging in scope from broad biological surveys of certain local areas, both land and water, to detailed studies of species. This basic survey of the flora and fauna of the state is still in process of completion, but the emphasis rests today on groups of smaller organisms about which less is known.

Another phase of this earlier program of the Natural History Survey may be truly considered as economic biology, and the threshold of what now is referred to as wildlife resources management. I refer here primarily to a series of papers on the food of birds and fishes, and on the numbers and distribution of birds in various sections of the state. This early work on the food of birds, by S. A. Forbes, has been referred to by Weed and Dearborn (1903) in their book entitled *Birds in Their Relations to Man* as furnishing "the basis for the modern development of economic ornithology," and by McAtee (1917) who states in a more recent publication that this work, together with the work of another early ornithologist, is the foundation "of the scientific method of studying the economic value of birds." The Survey bulletins of Forbes and Gross (1921-1923) are representative of the present census technique of today's game management studies. A series of reports on forestry in Illinois from 1910 to 1926 certainly paved the way to a great extent for the introduction of public ownership and management of forested lands in Illinois and state forestry agencies now in existence.

Beginning in about 1934, in addition to a continuation of efforts to complete basic surveys of the flora and fauna, special emphasis began to be placed, in the sections of the Survey dealing with fish, game and forests, upon the management of these resources. Management, whether of fish, game, fur bearers, or forests, is the act of making such resources produce sustained crops. These crops may be for recreational uses, a combination of recreational and utilitarian uses, or complete utilitarian uses. When we arrive at the point of complete utilitarian uses of our wildlife resources, we have entered the field of animal husbandry.

Although certain aspects of wildlife management have been practiced in Eurasia for a long time, the altering in America of environments or ranges according to biological principles, for greater productivity of desired renewable natural resources, is comparatively recent. This is understandable on the basis that our culture is young and we are close to generations whose almost total existence was taken from the woods, waters and soils of our domain. Even today, in the midst of a great industrial development, as individuals we cling to a heritage of public rights in renewable natural resources, particularly forests, fish and game, and through intimate personal con-

* Chief, Illinois Natural History Survey, Urbana, Illinois, Retiring President of the Academy.

tact with these resources preserve a culture which is peculiarly American.

In a paper presented in the General Session of this Academy in 1934, I gave a six-point summary of my ideas held at that time for a land utilization program in Illinois for forestry, wildlife and recreation. It is cheering to note that there have been worthwhile accomplishments under each of these points, including the establishment of a National Forest in southern Illinois, additional state and county forests, expansion of the state park system, establishment of upland game and migratory waterfowl sanctuaries, and the ending of large-scale promotional and exploitational schemes detrimental to renewable natural resources. These developments during the past decade have been the result of the activities of many agencies and individuals, but I am happy to state that, within the state, the Natural History Survey has played an important, often pivotal, part in each of them.

As previously mentioned, special emphasis upon the management of the state's renewable natural resources by the Natural History Survey dates from about 1934, the year in which the first game technician was appointed to the staff. Although an aquatic biology section was functioning long prior to this date, its program, too, became subject to reorientation along management principles about this same time. In 1935 a Mid-Western Wildlife Conference was organized at Urbana, sponsored by the Survey, to serve as a clinic and clearing house for the views and conclusions regarding wildlife resources investigations in the central states region.

The next big step in organization for renewable natural resources research came in 1937, when appropriations were obtained to increase the staff, construct field laboratories, and establish experimental areas. This program was again augmented in 1938, in cooperation with the Illinois State Department of Conservation and the U. S. Fish and Wildlife Service under the Federal Aid in Wildlife Restoration Act.

The preceding statements about past accomplishments and more recent advancements in the organization of the Natural History Survey for researches in the field of the renewable natural resources of Illinois have, perhaps, brought to mind questions regarding the general objectives of such a revised program and also regarding recent results from these investigations.

One of the phases of any investigation of valuable renewable natural resources is the establishment of accurate and impartial data regarding each resource as a guide to insure its preservation or its management on a maximum or sustained yield basis. Seldom do we find the simplest of the required basic data available or in such form that they can be utilized without reworking. When dealing with wildlife management problems, we must have reliable information concerning a large number of matters. For instance, in the case of each wildlife species involved, we need a close approximation of its numerical abundance, its distributional pattern within the state, what constitutes its most favorable natural breeding territory; and we need to know if there are measurable swings over a period of years from low to high populations and back again. We need to know about the breeding seasons of the species involved; and much other biological information. It must be understood that for best management results each species of fish, fur bearer, migratory waterfowl, upland game bird, or other renewable natural resource unit, must be studied separately in respect to such matters, and then again from the standpoint of its relation to its total environment.

Although the sum total of these investigations is a big and long-time order for any agency, many of the techniques necessary to secure the data, as well as much of the desired information and needed basic generalizations, are being obtained at a comparatively rapid rate. Thus it happens that even in the midst of a youthful program and the establishment of necessary preliminary basic data, the Survey is now actively pursuing some phases of the ultimate objectives of a state-supported renewable resources study; namely, the development of practical methods and information for resources preservation and utilization for the benefit of the general public. In support of this statement, it is possible to cite many examples where the results obtained to date are accomplishing their purposes. I have time to mention only a few such instances, selected to show the variety of

Fig. 1.—Male of the prairie chicken, once an abundant and valuable bird in Illinois, now in need of protection and further study.

ways in which scientifically acquired renewable natural resources information can be utilized to attain desirable goals.

Studies of the prairie chicken reveal that efforts directed toward the management of this splendid bird, so familiar to the early settlers in Illinois, must of necessity focus almost entirely around the preservation of a small number of remnant flocks, and any proposals for the removal of this game bird from the list of protected birds under present agricultural conditions should be opposed. Furthermore, favorable nesting territory is such that any grandiose schemes for the propagation and release of the prairie chicken in numbers throughout the state, with the hope of permanently supplementing game birds for hunting purposes, is foredoomed to dismal failure. Our studies of prairie chickens, therefore, may already be confidently used to prevent undesirable game law legislation and unwise expenditures of conservation monies.

Information in hand concerning rabbits, which, by the way, are an important item in the meat diet of many families in certain parts of this state, gives us an altogether different type of conclusion. In the management of this resource we can recommend a limited amount of utilization along with preservation. We now know that great fluctuations exist in the abundance of this animal from year to year, and that this rise and fall in numbers, over a period of years, is a normal expectation. It is sound management, therefore, to recognize that the cropping of this resource — an estimated 3,000,000 pounds went to market annually preceding 1937—could be considerably increased, at least in certain peak years, without permanent impairment of our necessary basic breeding stock.

For some years there has been a lively controversy in this state regarding the soundness of the time of the open season for the hunting of squirrels; another resource which, without attracting much public attention, makes a considerable contribution to the meat diet of many families, particularly in the central and southern parts of this state. The settlement of this argument depends upon the definite establishment of information pertaining to the time and duration of the breeding season in different game zones. It would seem to most people, because of the commonness of squirrels, that trustworthy information about breeding seasons would be already available, but this was not so when Natural History Survey studies, made in cooperation with the State Department of Conservation and the U. S. Fish and Wildlife Service, were begun. Investigations are now in course

Fig. 2.—Through the banding of waterfowl, Illinois Natural History Survey wildlife technicians gather data on migration habits, travel lanes, kill and survival ratio, and other data that will lead to recommendations designed to prevent depletion of these valuable birds that suffered following the first World War.

of completion which will give authoritative answers to the questions involved, and thus serve to influence game law legislation which will insure proper hunting seasons, and thereby the intelligent cropping of this resource.

At this time, a detailed report on the fur resources of Illinois is in preparation. The fur bearers are now known to contribute about $1,000,000 annually to the income of Illinois families, chiefly in the low income group where it is most

Fig. 3.—The place of native waterfowl food plants in relation to the millions of waterfowl that use the Mississippi-Illinois flyway is being studied by the Illinois Natural History Survey. Shown here is a bed of rice cut-grass, one of the best of the native plants.

Fig. 4.—For effective management of small artificial lakes, techniques must first be developed in experimental bodies of water. The recording thermograph shown here is one of the instruments by which Illinois Natural History Survey technicians study the influence of temperature on fish production.

needed. If anything is ever to be done toward a managed increase of this important resource, this report will be basic to that undertaking.

The data obtained in the course of the Survey's fisheries investigations have been quite revolutionary and counter to many generally held ideas concerning ways to improve fishing. This phase of research management investigations is gradually approaching the techniques of a more mature animal husbandry program.

Time will not permit me to go into further detail concerning the many and varied projects in the renewable natural resources field now under investigation by the Natural History Survey. The re-

Fig. 5.—Two fish technicians at work in the new Illinois Natural History Survey laboratory at Ridge Lake, near Charleston. Oxygen content of water and other scientific data are determined as part of the experimental program that will lead to recommendations for improved growth rates of fish in small artificial lakes.

sults from this work are rapidly accumulating, and I am certain that they are destined to influence profoundly the preservation and utilization of the state's renewable resources; in fact, this scientific basis for state action is already taking place.

In an earlier part of this paper, while broadly reviewing the general objectives of the Survey's present applied program, I called attention to the youthfulness of these investigations. This is an admission that in many instances we are involved in a long-time program, and that from many problems now under investigation no conclusions can be drawn for some years to come. Cyclic fluctuations cannot be determined by a year or two of observations, nor can game management policies for our most intensively farmed areas be promulgated on the basis of study areas two or three years old, with plantings which require some years for mature growth. Determinations of balanced fish combinations to be used in stocking new reservoirs and the best methods of cropping must be tried in many localities and under varying conditions. All such programs demand a reasonable amount of continuity and time.

Now, just when we are virtually getting started on a new program of practical management studies of resources, the greatest war of all time is thrust upon us. If it took a major depression to awaken Americans to the realization that renewable natural resources are important to our well-being, and that we must initiate scientifically planned researches to insure their continued existence and use, I feel safe in asserting that this war will drive home to all the absolute necessity of our varied resources to our standards and ways of living. Some resources, to be sure, are more important, at least for the moment, than others, but it is all of them

Fig. 6.—Properly managed artificial lakes in Illinois can produce good catches of bass and other desirable fish, as shown by this scene at Lake Glendale, in the Shawnee National Forest.

together, each in its place, which have made the United States the envy of the rest of the world, and the nation which we cherish today.

Concessions to the war effort must, and will, be made by all individuals and every normal program. Already, the Survey is reorienting its program to aid the war effort as best it can. The renewable resources of both state and nation will contribute their share in the support of our cause in the form of food, clothing, and in many other forms.

As an example of this support, let me cite the case of one renewable natural resource scarcely mentioned heretofore in this address; namely, forest products. It has been stated by Ovid Butler, of the American Forestry Association, that each of our forests must give at least five trees to equip and maintain each man in our armed forces. These trees are used to give him his living quarters and training camp, the wooden crating necessary to ship him food, clothing, tanks and guns, for the making of high explosives, bombers and battleships; in fact, virtually every piece of equipment necessary to wage modern war.

While we must open our resources to the nation in its time of greatest need, we must be on guard, also, to prevent

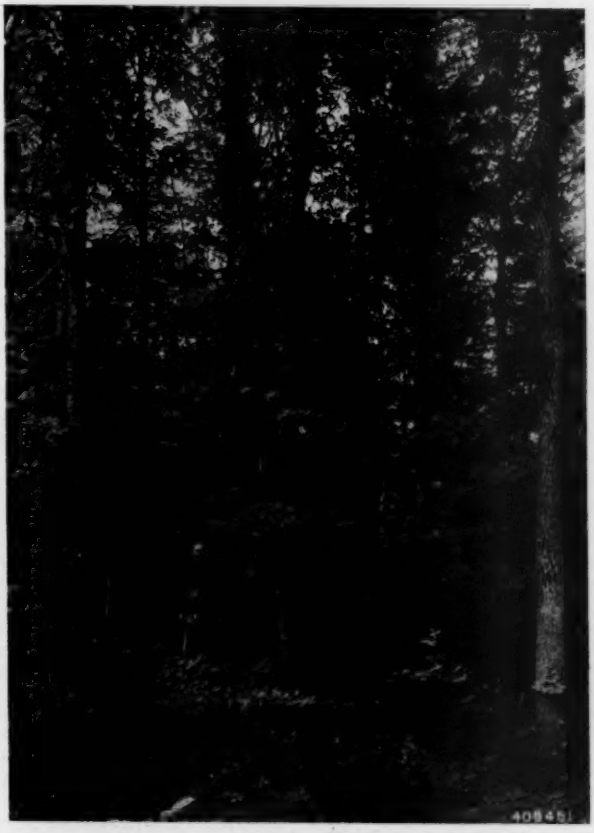


Fig. 7.—Stand of white oak timber in the Shawnee National Forest, southern Illinois. Publicly and privately owned forestry resources of the state can contribute materially to the war effort, but exploitation that is unnecessary and permanently injurious should be studiously avoided.

exploitation that is unnecessary and permanently injurious. Many proposals are apt to be put forward under the guise of the national war effort which are valueless, and they must be rigorously opposed by technical agencies.

Although I will not have time to elaborate upon this subject, the recreational uses of wildlife resources will contribute greatly during the coming months to make our war efforts successful. The benefits from outdoor recreation are exceedingly difficult to evaluate in dollars and cents, but, nevertheless, we know that mental and physical health is expensive to rebuild and that some recreation is essential.

I cannot resist closing this address with a prophecy; to wit, that after the war renewable natural resources programs will be sponsored by the state and nation more than ever before. These programs to be worth anything should have the guidance of experienced scientific organizations. Such agencies cannot be assembled over night. So, let us hope that while giving everything necessary to win the war, we will have the vision to preserve the essentials in scientific endeavors as the spring board for our country's rejuvenescence after the war.

(This talk was followed by a colored motion picture showing activities of the Illinois Natural History Survey relating to research on wildlife resources.)

THE BETATRON*

D. W. KERST, University of Illinois, Urbana, Illinois

FROM THE experiments of the past eleven years and from still earlier experiments we have learned a great deal about the phenomena of nuclear disintegration, especially about artificially produced disintegration, which follows as a result of nuclear particles being forced together so that some degree of interpenetration occurs. Since the nuclei of atoms are positively charged, the great repulsive forces arising from a very close approach must be overcome before there will be penetration. One cannot take a hold of nuclear particles or push directly on individual particles; so the method which has been used with such great success is that of impact. Charged nuclei, or positive ions, of one variety are accelerated in a high voltage vacuum tube in which the electrodes are arranged to force them toward a target of a substance containing the other nuclear particles to be bombarded. It is common in these artificial disintegration experiments to reach forces as great as 20 pounds weight between individual nuclei during the impact process. This force is far out of the range of those which occur in the most intense compression that can be produced by other means.

It is only in the case of the neutron, the uncharged nuclear particle, having approximately the same mass as the proton, that penetration into other nuclei occurs easily, and this is because the lack of charge on the neutron makes electrical repulsion impossible.

One other reason for giving one of the nuclear particles a high energy is that when the two nuclei collide certain reactions will not occur unless the energy brought to the collision by the high speed particle is sufficient to supply the energy required for this reaction. It is mainly for this reason that if disintegrations are to be produced by electrons or by the x-rays which they produce, the electrons must have very high energy.

The nuclear physicists who have become high voltage experts in order to do these disintegration experiments make use of several varieties of high voltage apparatus to impart large energies to small particles. Except for disintegrations produced by particles from naturally radioactive substances, the equipment usually used for producing high speed particles has been either a linear accelerator or a cyclotron. In the linear accelerator the charged particles are pushed from electrode to electrode down the axis of a long vacuum tube. The electrodes are generally hollow cylinders connected to successively higher voltages. The voltage is supplied either by a large transformer-rectifier combination or by the Van de Graaff type of electrostatic generator which charges a high voltage electrode by means of long moving belts. One end of the accelerating tube is connected to this high voltage electrode, and the other end is usually at ground potential. This accelerator has been developed to the extent where it produces about 4.5 million volts when confined in a tank no larger than 5.5 feet in diameter and 22 feet long, provided the high air pressure of about 100 pounds per square inch is used for insulation of the high voltage terminal. This type of accelerator has been used to some extent for the study of nuclear reactions produced by electrons and x-rays having energies up to three million electron volts, but most of the work of the electrostatic accelerator has been with positive ions. There is a large number of nuclear reactions called photodisintegrations which can occur by electron or x-ray bombardment, but these require on an average six to eight million electron volts of energy before the reaction can proceed. For these experiments energies greater than those obtained by the electrostatic generator are necessary.

In the cyclotron the positive ions do not follow a linear path. Rather they are bent by a magnetic field into a spiral path, and they are accelerated back and

* Invited paper presented before the Physics Section meeting at Urbana, Ill., May 8, 1942.

forth between two dee shaped hollow metal electrodes. The reason this can be done is that when a group of positive ions are well shielded within one of the dees this electrode reverses potential with the other electrode; and by the time the positive ions are in position to pass to the other dee, the potential is such that they are forced forward to a greater speed. This requires that the dees be connected to a high voltage high frequency oscillating circuit. The final energy which the positive ions achieve is the product of the number of transits from dee to dee and the voltage between dees. With this apparatus deuterons have been accelerated to 16.5 million electron volts, far more than the voltage which can at present be produced on a single insulated electrode such as that used on the electrostatic machine.

However, the cyclotron cannot apply its great voltage to electrons. The reason for this lies in the onset of relativistic behavior of the electron at very low energies. Particles behave in a distinctly relativistic manner when their kinetic energy approaches or exceeds the energy equivalent of their rest mass. For example, the rest mass of a proton is equivalent to about one billion electron volts. Protons of this energy would show pronounced relativistic behavior; however, the electron with a rest mass equivalent to only .5 of a million electron volts will behave relativistically at this low voltage. At .5 of a million electron volts the electron is traveling at approximately .9 of its speed limit, the velocity of light. Since one of the requirements in the operation of a cyclotron is that the accelerated particle increases its speed in proportion to the square root of the number of revolutions, it is impossible for an electron near its speed limit to fulfill this condition. Consequently, a cyclotron could only be used for electrons at voltages well below half a million volts.

Fortunately the betatron operates equally well at classical or relativistic energies. The energy which the new betatron gives to electrons is 20 million electron volts. With this source of high energy electrons one can create extremely energetic x-rays, and the nuclear-photo effects requiring on an average 6 to 8 million volts can be produced. Generally in the photo effect an x-ray or gamma ray photon of energy greater than the binding energy of a neutron within the target nucleus reacts with that nucleus and ejects the neutron somewhat like the electrons are ejected from the cathode in an ordinary photo-electric cell. The resulting nucleus is frequently radioactive, and the binding energy of the nucleus to be disintegrated can then be easily determined by finding the energy of the betatron at which production of radioactive material commences. The electrons themselves can be used to eject the neutron for the nucleus responds to the passage of an electron with its associated electric field in the same way but to a lesser extent than it responds to high energy photons.

Since we now have available a source of highly penetrating x-rays and a source of electrons of an energy so great that they can penetrate approximately half way through the human body, the uses to which the betatron can be put are not only experimental but very practical. X-rays are widely used in numerous practical ways industrially, and the radiations from the betatron are more penetrating than any others which have been produced.

The high energy electrons which escape from the accelerator by scattering off of the x-ray target form a very intense but somewhat divergent beam of electrons. Such high energy electrons when sent into the human body would produce a trail of ionization having the same destructive effect as x-rays which are at present used for therapy of deep tissue. One of the disadvantages of x-rays is that they do not stop somewhere within the body, but they penetrate completely through it and produce a biological effect, not only at the entrance surface and at the tissue being treated, but also at the exit side of the body. Various techniques are used in an attempt to create an optimum of ionization at the deep malignant tissue; but the advantage which penetrating electron rays have is that their range is finite and proportional to the energy of the electrons. The 20 million volt electrons from the betatron would penetrate 10 centimeters into the body and no more. Dr. Phillip Morrison estimates that the maximum ionization produced by these rays would be at about 7 or 8 centimeters below the entrance surface of the body. This means that the damage produced by an electron beam

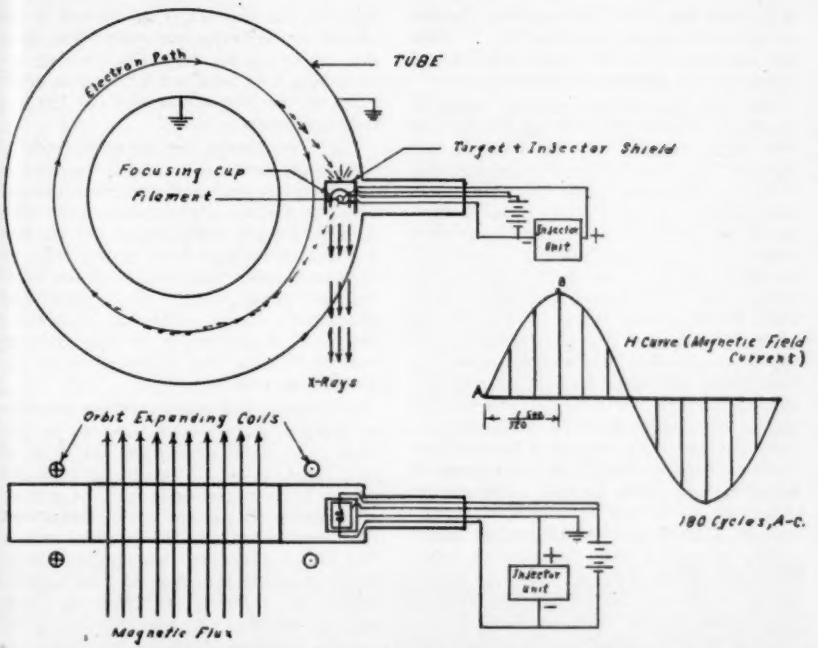


Fig. 1.—The vacuum doughnut in which the electrons are accelerated. Electrons going from the injector to the equilibrium orbit actually circle the tube many times before reaching the orbit. The same is true for electrons leaving the orbit to hit the target. Electrons are injected at A, and the orbit is expanded at B in every cycle.

can probably be localized fairly well on the tissue which is irradiated, a smaller amount of damage being done on the entrance side of the body and no damage being done beyond the tissue irradiated. When the beam of electrons in the betatron can be brought out without being scattered from a target, it will be more homogenous and less divergent, which will make the betatron more applicable to this very practical problem.

OPERATION OF THE BETATRON

The betatron looks in some respects like a miniature cyclotron since it is a magnetic device; but it operates with an alternating magnetic field instead of a uni-directional field. The theory of the betatron shows that relativistic effects encountered when the speed of light is approached do not hinder the operation in any way.[1] Electrons from an electron gun, called the injector, are shot into a circular path in a low intensity magnetic field. As these electrons circulate between the poles of the magnet, the magnetic field increases, and the time rate of change of flux linking the orbit produces a voltage gain per revolution equal to the voltage which would be read on a voltmeter connected to a one-turn coil placed at the orbit and reading instantaneous voltage.

Fig. 1 shows a sketch of the circular vacuum tube or doughnut in which the electrons leave the injector, circulate the magnetic field many times picking up energy at every revolution, and strike the back end of the injector, after they have been accelerated, where they produce x-rays. The orbit expanding coils are energized after the electrons have been accelerated, and they disturb the flux distribution near the electron path causing the electrons to spiral out to the target. The electrons are injected at the time indicated by A on the graph of magnetic

[1] D. W. Kerst, Phys. Rev. 60, 47 (1941). D. W. Kerst and R. Serber, Phys. Rev. 60, 53 (1941).

field, and the orbit is expanded to the target at the time indicated by B when the energy is at its maximum. These processes are repeated in each cycle.

The increase in flux linkage supplies momentum to the electron, and were not the magnetic field at the orbit of the electron increasing simultaneously, the orbit would become larger and larger and soon strike the outer wall of the acceleration chamber. To hold the electron in a fixed orbit it is necessary to make the magnetic field at the orbit increase in proportion to the momentum produced by the increasing flux linkage. The radius of curvature, r, of the orbit is related to the momentum of the electron and the size of the magnetic field, H, as follows: $mv = (e/c)\ Hr$. This calls for a special distribution of magnetic flux density, as we shall see. By Newton's second law the time rate of change of momentum is equal to the force on the electron; or $d(mv)/dt = f$, and the force, f, is the energy gained per centimeter of path, which assuming that the electron orbit has a fixed radius, r, is $(e/c)\ \phi/2\pi r$ where ϕ is the flux linking the orbit, e the charge of the electron, and c the velocity of light. Integrating the time rate equations, we get $mv=(e/c)\ (\phi-\phi_o)/2\pi r$, showing that the momentum is proportional to the change of flux within the circular orbit. Equating this momentum to $(e/c)Hr$ we get $\phi-\phi_o=2\pi r^2H$; which shows that if ϕ_o is zero when H is zero, the flux linking the orbit is proportional to the field at the orbit and must at all times have the value twice that which would exist if the field H were uniform within the orbit.

This result was obtained by making the assumption or r constant. Naturally the converse must be established and was established before the accelerator was built, that is, given this flux distribution, then the orbit has a fixed radius.

No mention has been made of the time dependence of the flux and field. It is merely necessary that the flux increase with time and that the field increase proportionately. This is easily accomplished by having both H and ϕ produced in an air gap by the same magnetic circuit. In practice the magnet and its coils correspond to an inductance in a resonant circuit. A great number of condensers are used to produce resonance at the desired frequency. On the original betatron made at the University of Illinois a frequency of 600 cycles per second was used, and 180 cycles per second is used on the 20 million volt betatron which was made while on leave of absence at the General Electric Company.

The requirement for the production of a beam of electrons in the accelerator is that stray or scattered particles deviated from the desired orbit by encounters with the residual gas molecules in the vacuum chamber be brought back to the orbit by focusing forces. The stray electron must oscillate about this orbit, called the equilibrium orbit, with a decreasing amplitude of oscillation, or the damping must be so great that it never crosses the equilibrium orbit.

By shaping the magnetic field properly the conditions for oscillation can be fulfilled. For axial oscillation the lines of force must bulge outwardly between the poles. The electron finds itself in a magnetic field with a slight radial component if it deviates from the median plane. This radial component has opposite directions on opposite sides of the median plane, and it forces the electron back toward this plane no matter which way the displacement occurs. To make the field bulge outwardly between the poles it is merely necessary to have the air gap increase with increasing radius. In practice this is done with approximately conical pole faces except for a slight lip at the rim of the pole face to correct for the rapid drop in field intensity which occurs at this point.

The condition for radial oscillation is that the magnetic field must not decrease more rapidly than 1/r. This can be understood from Fig. 2 which shows the curve of required centripetal force to hold the electron in the radius, r, as a function of r. This is a hyperbolic curve, since $F_c = m\ v^2/r$. The magnetic force Fm which is supplied by the magnetic field is $F_m = (e/c)\ H\ v$. In the betatrons which have been made, v changes so slightly during several focusing oscillations that this change can be ignored for the present. Consequently, if the radial dependence of Fm, and hence of H, is as shown in Fig. 1, it will supply more than the required centripetal force when r is greater than r_o and less when r is less than r_o. Should an electron be outside the equilibrium orbit, it would be in a region where the magnetic field was stronger

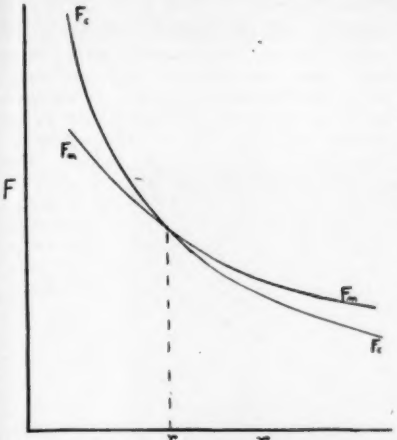


Fig. 2.—$F_c \triangleq mv^2/r$ is the centripetal force required to hold the electron in a circle of radius, r. $F_m = (e/c)Hv$ is the magnetic force which is actually supplied to the electron. The equilibrium orbit is at r_o.

than that necessary to cause a circular path. Its orbit would bend in toward the equilibrium orbit and, on crossing, the electron would find itself in a region where the magnetic field does not quite supply the required centripetal force; so the electron goes outwardly. This oscillation about the equilibrium orbit eventually dies out. The decrease in the amplitude of oscillation is a result of the increase in the magnetic field during the period of oscillation. The amplitude is proportional to $H^{-\frac{1}{2}}$. To a certain extent this is analogous to the stiffening of a spring which holds an oscillating mass. The damping properties of the increasing magnetic field make possible the whole process of injecting electrons so that they are trapped in a fixed orbit.

These axial and radial focusing actions succeed in forming a minute electron beam which strikes the target at a small focal spot. The x-rays produced cast very sharp shadows because the rays come from practically a point source.

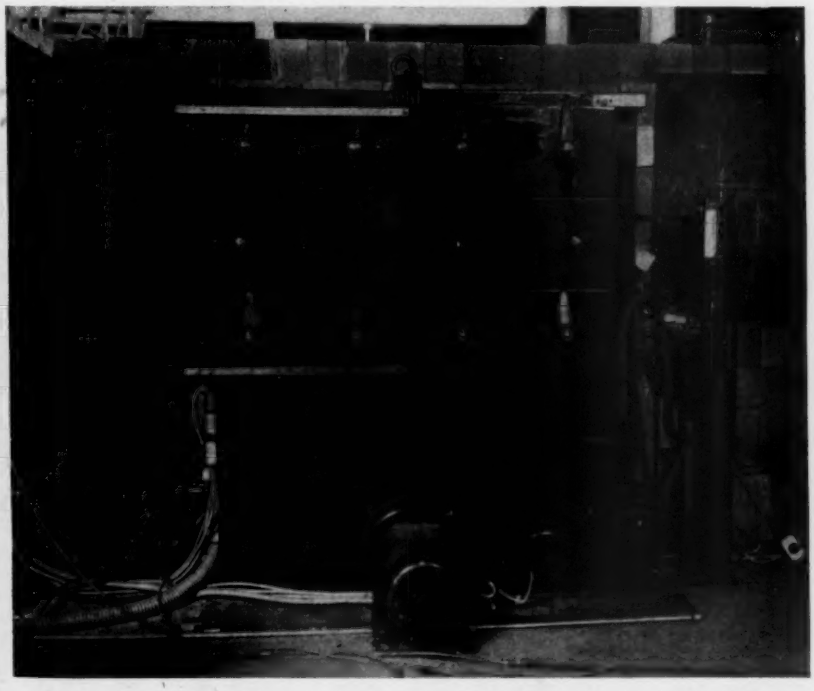


Fig. 3.—The new 20 million volt betatron. The light showing in the doughnut between the poles is from the injector.

The target is not melted by this fine beam because very little current is used. Approximately one microampere in the 20 Mev betatron suffices to produce 16 r per minute at one meter. The total number of watts in the beam is thus 20 and at this high energy the efficiency of x-ray production is so great that about 65 per cent of this beam energy is given off in x-rays and only the remainder heats the target.

The photograph in Fig. 3 shows the new 20 million volt betatron with the light coming from the injector at the edge of the doughnut between the poles. This accelerator has a 19-inch pole face diameter and an equilibrium orbit of 7.5 inches radius. The magnetic structure is only three feet high and five feet long; but it weighs about 3.5 tons. It requires about 25 kilowatts to operate it at 20 million electron volts at an oscillating frequency of 180 cycles per second. The cooling of the magnetic circuit is provided by the blower in the base of the magnet.

Not only is this accelerator capable of producing the usual x-ray effects with rays of greater penetration, but the radioactivities produced by photodisintegration in numerous substances have been observed, and the energy is sufficient for some small scale cosmic ray effects.

A NATURALIST IN THE SOUTH SEAS

EXCERPTS FROM LECTURE BY KARL P. SCHMIDT

Chief Curator, Dept. of Zoology, Field Museum of Natural History, Chicago, Illinois

THE ROMANTIC interest in museum expeditions to far-away and exotic regions in search of collections for study and display is still greater when such an expedition is foot-loose in a beautiful sailing yacht and one is able to visit out-of-the-way islands and cast anchor in little visited ports. . . . . Our glimpse of the islands of the Pacific will take us through the Polynesian Archipelagos, to the islands of Melanesia, inhabited by curly-headed black peoples, and to the great island of New Guinea, now so familiar and so vitally important to us in the daily news.

The Galapagos Islands have formed a focus of biological interest since the visit of Charles Darwin in 1835, and have become familiar to naturalists during the following century from the visits of successive expeditions and groups of scientists. It is noteworthy that the scientific interest of these extraordinary islands is not yet exhausted, and that they are now of the utmost political and military interest to us in the present war.

Far-off islands and ports visited by the Crane Pacific Expedition have now fallen into the hands of the Japanese. It is interesting that one of the services naturalists can offer to the war effort springs from their knowledge of the geography of such regions, now suddenly become of the most vital importance to us and to our sons.

(This lecture was accompanied by colored slides.)

FRANK COLLINS BAKER

DECEMBER 14, 1867, TO MAY 7, 1942

THOUGH he never at any time held a teaching position, few scientists of the present day have had greater influence in directing and stimulating interests of students than had Frank Collins Baker. Through his genial personality, his generous kindliness, his published researches, and his displays in museums, unnumbered thousands are included within the sphere of his scientific influence. Several prominent younger scientists, in such diverse fields as geology, anthropology, entomology, and zoology have acknowledged Mr. Baker's kindly and sympathetic interest as one of the important factors in their ultimate determination to devote their lives to scientific pursuits. But these careers, directly motivated by contacts with an understanding spirit are but one item in the evaluation of his broad influences.

Under his guidance the system of loan exhibits for the Chicago schools was inaugurated by the Chicago Academy of Sciences. As an outgrowth of this program thousands of children were given their first contacts with and interest in the study of nature.

His published works, especially those on the Mollusca and on the Life of the Pleistocene, have been and continue to be source books for all students of these subjects.

Mr. Baker became, for a short time, curator in the newly established Field Columbian Museum in Chicago (1894) after having received professional background and training in Brown University, in the Philadelphia Academy of Sciences, and in Ward's Natural Science Establishment of Rochester, New York. This was followed immediately by his appointment to the curatorship in the Chicago Academy of Sciences (1894-1915) where he developed techniques of museum display along with an absorbing interest in research.

For two years (1915-1917) he carried out a most comprehensive evaluation of the relations of bottom faunas to fish life for the New York State College of Forestry, at Syracuse.

Following this period, at the height of his professional career, he became curator of the Museum of Natural History in the University of Illinois where he devoted 21 years (1918-1939) to building one of the finest teaching museums on this continent. All this while he was pushing forward a research program which

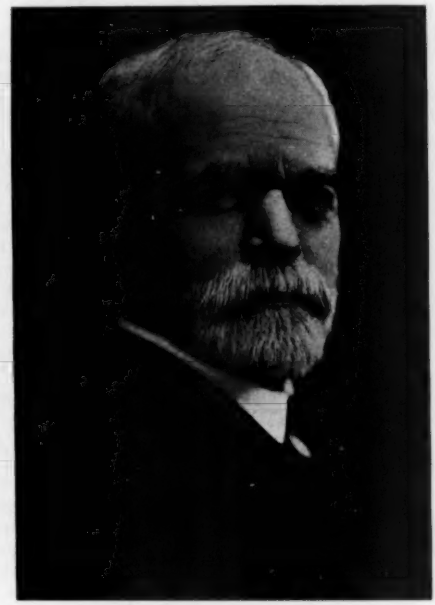
brought him eminence in the fields of the fresh water and land Mollusca and Pleistocene paleontology. Under his curatorship a third museum interest was expanded, namely, the building of study collections. The most widely recognized of these are in the fields of Mollusca, Paleontology, and Archaeology of Illinois.

Some of the scientific societies in which Mr. Baker held membership are: Fellow of the Geological Society of America; Fellow of the Paleontological Society of America; Fellow, American Association for the Advancement of Science; Corresponding member, Zoological Society of London; Life member, Illinois State Academy of Science (Sec'y. 1911, Vice-president 1931); Life member, Chicago Academy of Sciences (Sec'y. 1894-9; 1908); Museums Association of Great Britain; American Association of Museums (Councilor 1914-6); Ecological Society of America; Ottawa Field Naturalists Club; Sigma Xi; American Malacological Union (President in 1942).

Mr. Baker was a prolific writer. A complete list of his published books and articles totals close to 400 items. Of these, several stand out as distinguished contributions while the remainder comprise short notes and numerous more extensive articles. The best known of his books are *The Mollusca of the Chicago Area* (2 vols., 1892, 1902); *The Lymnaeidae of North and Middle America* (1911); *The Productivity of Invertebrate Fish Food on the Bottom of Oneida Lake, with Special Reference to Mollusks* (1918); *Life of the Pleistocene or Glacial Period* (1920); *Mollusca of Wisconsin* (2 vols., 1928); *Fieldbook of Illinois Land Snails* (1939).

Since his retirement from active service in 1939, as Curator *Emeritus*, he has devoted his full energies to research. Illness interrupted his work on a two volume monograph upon the Planorbidae which had been his major interest for many years. This work was expected to be the *magnum opus* of his research career. Death wrote the word "Finis" at the close of the manuscript for the first volume.

H. J. Van Cleave



EUGENE DAVENPORT

1856-1941

EUGENE DAVENPORT, born of pioneer parents near Woodland, Michigan, June 20, 1856, died on his old home farm, March 31, 1941, in his eighty-fourth year. He was graduated from the Michigan Agricultural College in 1878. After several years on his farm he returned to the Michigan Agricultural College for graduate work, receiving the degree of Master of Science in 1884. He was president of the Collegio Agronomica, Brazil, during 1891-92, serving as its first president. He became Dean of the College of Agriculture, University of Illinois, in 1895, Director of the Agricultural Experiment Station and Professor of Thrommatology, January 1, 1896, Director of the Agricultural Extension Service in 1914, and Vice President of the University in 1920, which position he held until his retirement on September 1, 1922. After his retirement he was recalled to active service to assist the President for a period of several months in 1929.

The honorary degree of Doctor of Laws was conferred upon Dean Davenport by Michigan State College in 1907, by the University of Kentucky in 1913, by the University of Illinois in 1931, and the degree of Doctor of Science by Iowa State College in 1920.

He was the author of several books and many articles in various periodicals. During the nineteen years of his retirement he did a great deal of lecturing and writing. His deeply ingrained characteristic of always seeing ahead, planning ahead, anticipating events was expressed at the end of his work for a bi-weekly agricultural journal to which he contributed a column. At the time of his death he had prepared enough material to

carry the column on for ten issues. Another important contribution since his retirement was a special investigation for the National Research Council.

To all of his work Dean Davenport brought clear thinking unhampered by petty details and prejudices which bias so many conclusions. His independence of thought and his far-reaching views of the problems of agriculture had their roots in the simpler pioneer life into which he was born and in which he lived through the most formative period of his life. His strength came not only from his love of people but from the great out-of-doors in which he found keen delight. In his book "Vacation on the Trail," he says concerning the mountaineer: "Brother to the peaks and the snow fields and the vast amphitheaters of green and white and gray that have guarded the passes since the world was young; friend to the timber, the waters, and the wild flowers; companion to the clouds and the shadows and drifting mists, the lightnings and thunders and the storms; neighbor to the very stars at night that seem to beckon one to step off the edge and be with them!"

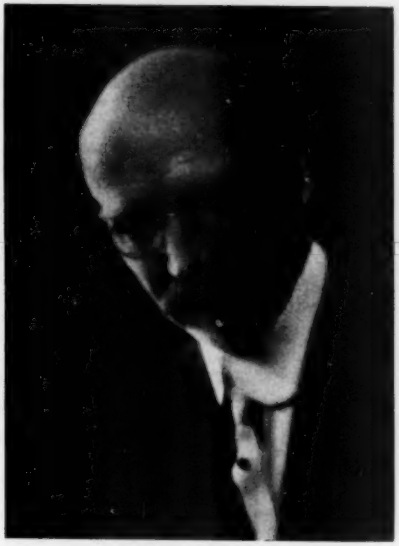
A statesman in all his approaches to educational and agricultural policy, Dean Davenport always considered the ultimate welfare of all the people. Temporary discomfort or even distress could be weathered, a slow beginning in a new venture could be tolerated, if the ultimate goal was right and the principles by which it was to be achieved would stand the test of time. At this point there was no room for compromise or expediency.

The core of his educational philosophy will be found in such statements as the following taken from an address which he gave in 1908. "The great mass of human happiness will always arise out of doing well the common things of life, and the happiness of the individual will lie in that creative genius which does today the same thing it did yesterday but does it better—the enduring things will always be the useful things. There will be no educated aristocracy, for education will have a higher purpose than to give one man an advantage over another. . . . There is no higher duty now resting upon all of us, and especially upon educators, than to unite education and activity by the closest possible bonds, to prevent on the one hand the acquirement of knowledge to no purpose, and on the other the development of operative skill with little knowledge of the true relations of things; to see to it that no individual shall be compelled to choose between an education without a vocation, and a vocation without an education. . . . What we need as a nation and a people is not simply more knowledge, but higher ideals. More of humility in success and more of fortitude in adversity. More of confidence in our fellows, and more of faith in the future."

Dean Davenport's influence was felt in all parts of the world, not only through the students who came to the University of Illinois from other countries, but as a result of his vigorous leadership in scientific research and educational policies. The esteem in which he was held was expressed in a message from Sir John Russell, of Rothamsted, England, which came to Dean Davenport on his eightieth birthday: "You have served not only your own country but the whole civilized world. May the rest of your days be in peace and in the knowledge that you have the affection of many friends in many countries."

In the passing of Dean Davenport we have lost a great leader, a man of high professional record and personal accomplishment, of rich service to mankind, a loyal friend—one with whom we are all proud to have been associated. Our consolation is that the influence and inspiration of such a life will continue in ways beyond our power to measure.

J. C. Blair
W. L. Burlison
H. E. Cunningham
C. F. Hottes
E. Roberts



FRANK SMITH

FEBRUARY 18, 1857, TO FEBRUARY 3, 1942

Frank Smith came to the Urbana campus in 1893. From the first, he held dual appointments on the staff of the Illinois State Laboratory of Natural History under Professor Forbes and on the University faculty in the Department of Zoology. His earlier experiences had consisted of collegiate training in Hillsdale College, in Michigan, and graduate study in Harvard, under Professor E. L. Mark, ending in a Master's degree in 1893. He had been Professor of Chemistry and Biology in Hillsdale College (1886-1892) and had taught Biology in Trinity College, Hartford, Connecticut (1892-3). The summers of 1886 and 1887 were spent in special study in the Anasquam, Massachusetts, marine station and that of 1891 found him under the influence of Alexander Agassiz in the Newport, Rhode Island, Marine Laboratory. The summer of 1893 he was engaged by the Michigan Fish Commission as a member of a group studying the biology of Lake St. Clair.

These early experiences in field laboratories peculiarly fitted him for the work which he was about to undertake for the Illinois State Laboratory of Natural History. He was made superintendent (1894) of the Biological Station on the Illinois River at Havana, under the joint sponsorship of the University and the State Laboratory. Here he helped to formulate and execute the early program of studies on the biology of the Illinois River.

The interests there aroused were kept alive at a much later date in his teaching of courses in field zoology in the University of Illinois and as a member of the faculty of the University of Michigan, teaching summers in the biological station on Douglas Lake.

In the University and throughout the Middle-west his long period of continuous service and his broad personal contacts made him a continuing agency between the old and the new developments in the zoological sciences. Not content to watch the opening up of the new fields, he took an active part in their development. As early as 1901 he was offering a course in Statistical Zoology in the University. In this course, before any specific instruction in evolution and heredity was given in the Department of Zoology, he taught the applications of mathematical analysis to

problems of "variation, heredity, distribution, and phylogeny."

His interests in teaching greatly influenced the direction of development of zoological courses in the University of Illinois, where he was advanced to a professorship in 1913. In 1923, Hillsdale College, his alma mater, conferred on him an honorary D.Sc. degree.

His earliest research was in marine zoology, but in the Middle-west, where he was to spend the remainder of his active career, he early undertook a program of studies on the earthworm fauna which led to his becoming recognized as the leading American authority on this group.

Another field of interest for both teaching and research was that of ornithology. Long years of daily observations on spring bird migration furnished data on which he correlated migratory movements with changes in wind and weather. After retirement, he found time and opportunity to carry on bird banding in his Michigan home during the summer months and in Florida during the winter.

From 1900 to 1917 he was curator of the museum of Natural History of the University of Illinois, performing this as a service to the University in addition to a relatively full program of teaching and research.

With his interest in the fauna of the state it was only natural that he was actively interested in the Illinois State Academy of Science, in which he held life membership. His memberships in scientific organizations were chosen with the same discrimination with which he chose his personal friends. They included the American Association for the Advancement of Science, the American Society of Zoologists, American Society of Naturalists, American Ornithologists' Union, and Sigma Xi. For many years he served as consulting specialist to the U. S. National Museum and to the U. S. Department of Agriculture.

The qualities of unassuming modesty and uncompromising honesty marked all of his relations with both students and associates.

H. J. VAN CLEAVE